USGS
science for a changing world

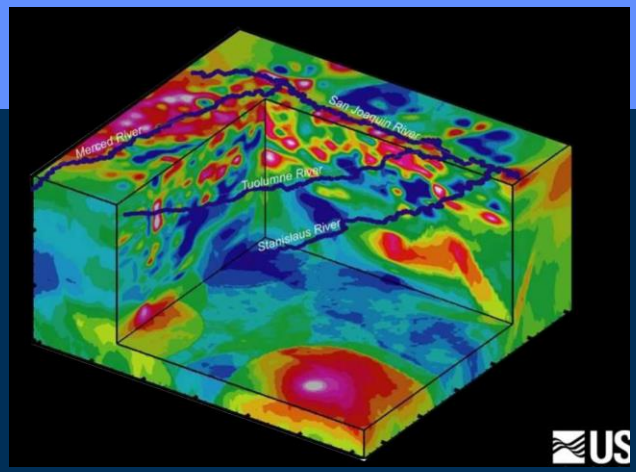
Oil, Gas, and Groundwater Quality in California—a discussion of issues relevant to monitoring the effects of well stimulation at regional scales

Kim Taylor, PhD, USGS California Water Science Center

U.S. Department of the Interior
U.S. Geological Survey

US Geological Survey
California Water Science Center

Mission is to collect, analyze and disseminate the impartial hydrologic data and information needed to wisely manage water resources for the people of the United States and the State of California



USGS

http://ca.water.usgs.gov/index.html

USGS Core Team

- Matthew K. Landon, Program Chief for Groundwater and Geochemistry
- Miranda S. Fram, PhD, GAMA Program Chief
- Justin T. Kulongoski, PhD, geochemist
- Pete McMahon, PhD, hydrogeology
- Claudia C. Faunt, PhD, Program Chief for Groundwater and Applied Modeling
- Kim Taylor, PhD, Program Officer

USGS

Framing the Problem

Where is the water and what does it already have in it?

Where is well stimulation occurring?

What mechanisms link well stimulation to the water?

How can we monitor those mechanisms?

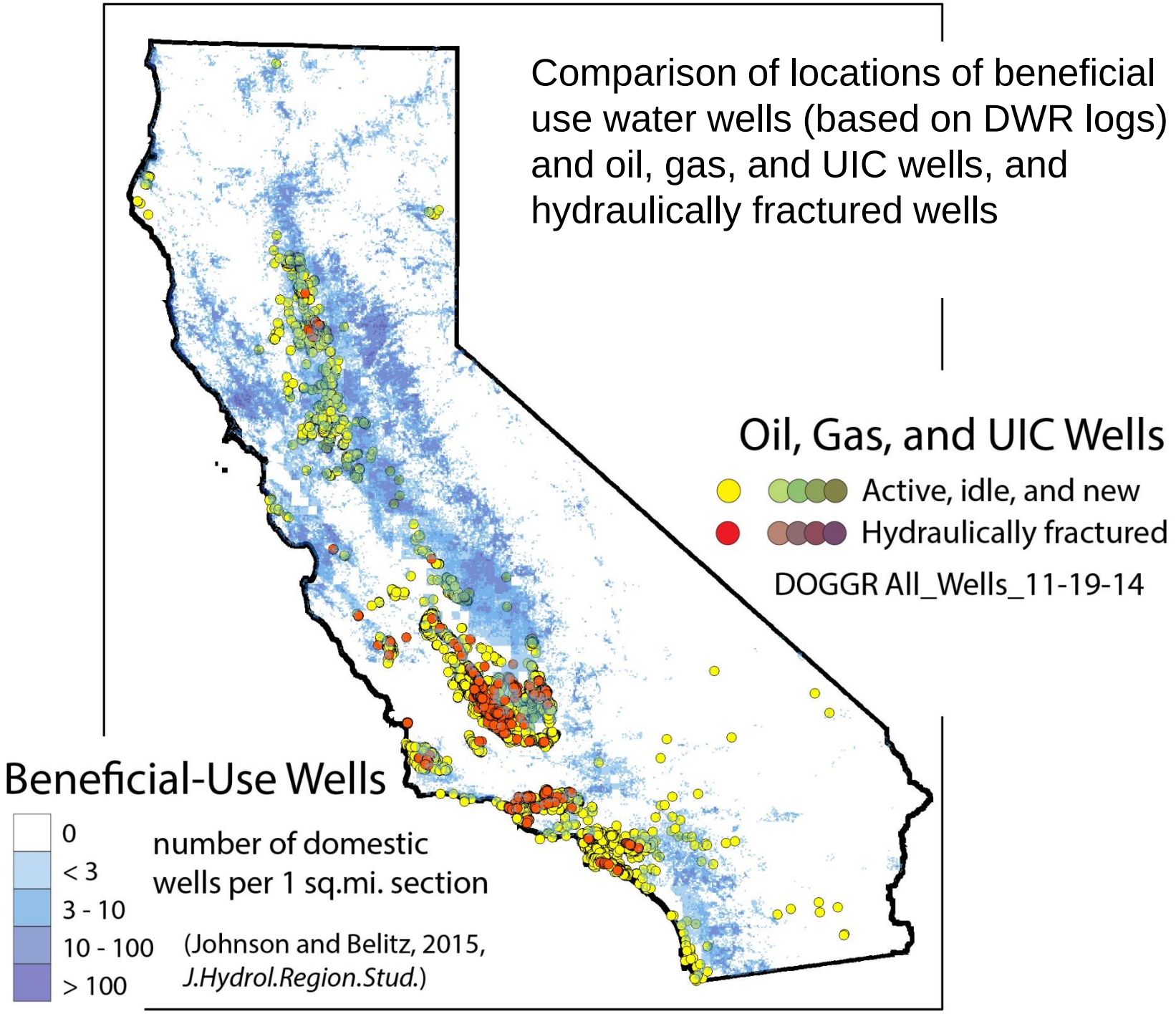
USGS

Where is fresh water?

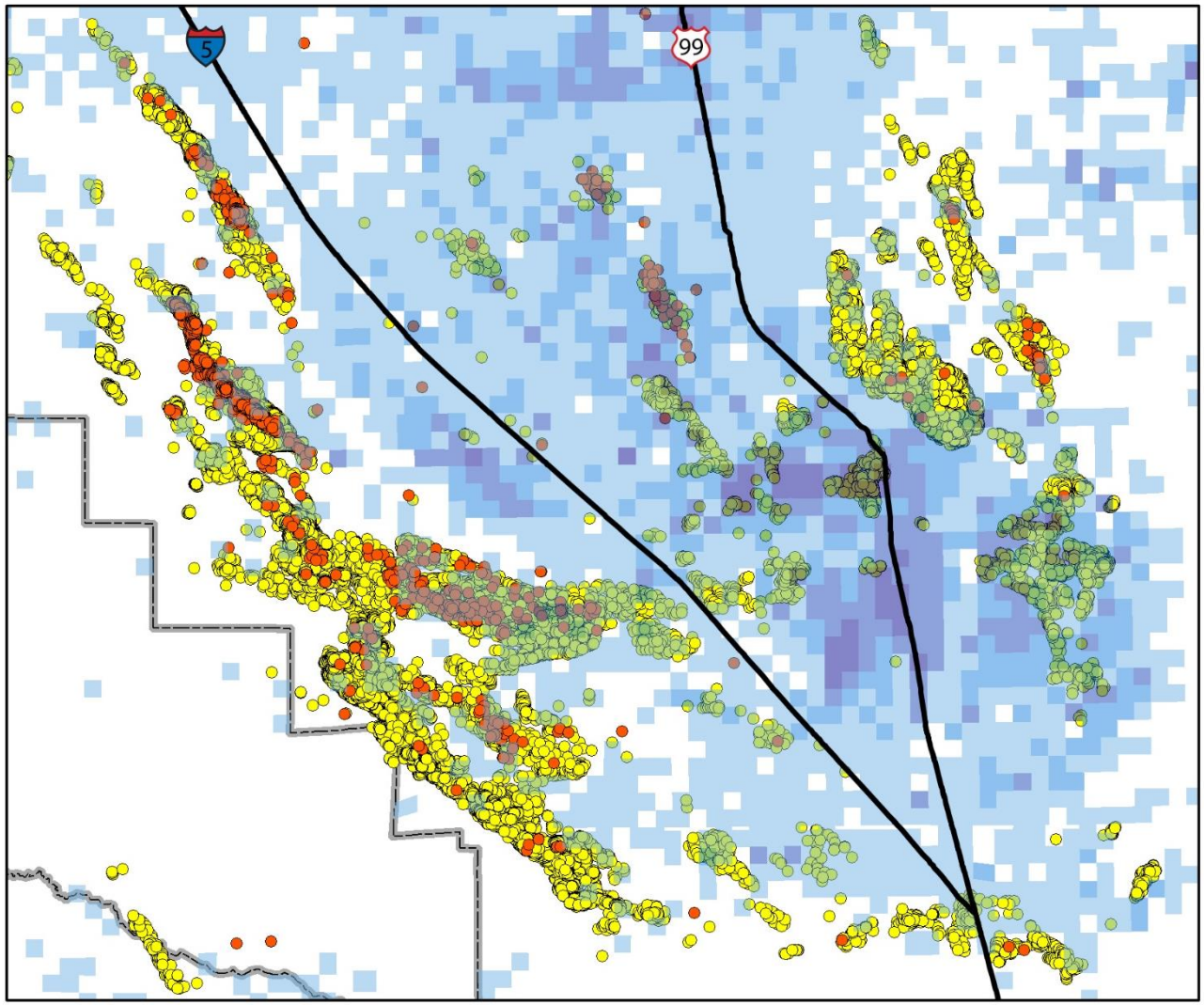
- No systematic delineation of aquifer zones containing less than 3,000 mg/l total dissolved solids
- Virtually no information on zones where salinities are between 3,000 and 10,000 mg/l total dissolved solids
- Current and future beneficial uses may not fit either category

USGS

Comparison of locations of beneficial use water wells (based on DWR logs) and oil, gas, and UIC wells, and hydraulically fractured wells



Kern County: Oil, gas, and UIC wells, and hydraulically fractured wells are located in areas with beneficial use water wells



Beneficial-Use Wells

0	number of well logs
< 3	per 1-sq.mi. section
3 - 10	(domestic, municipal,
10 - 100	irrigation, industrial)
> 100	

Oil, Gas, and UIC Wells

Active, idle, and new

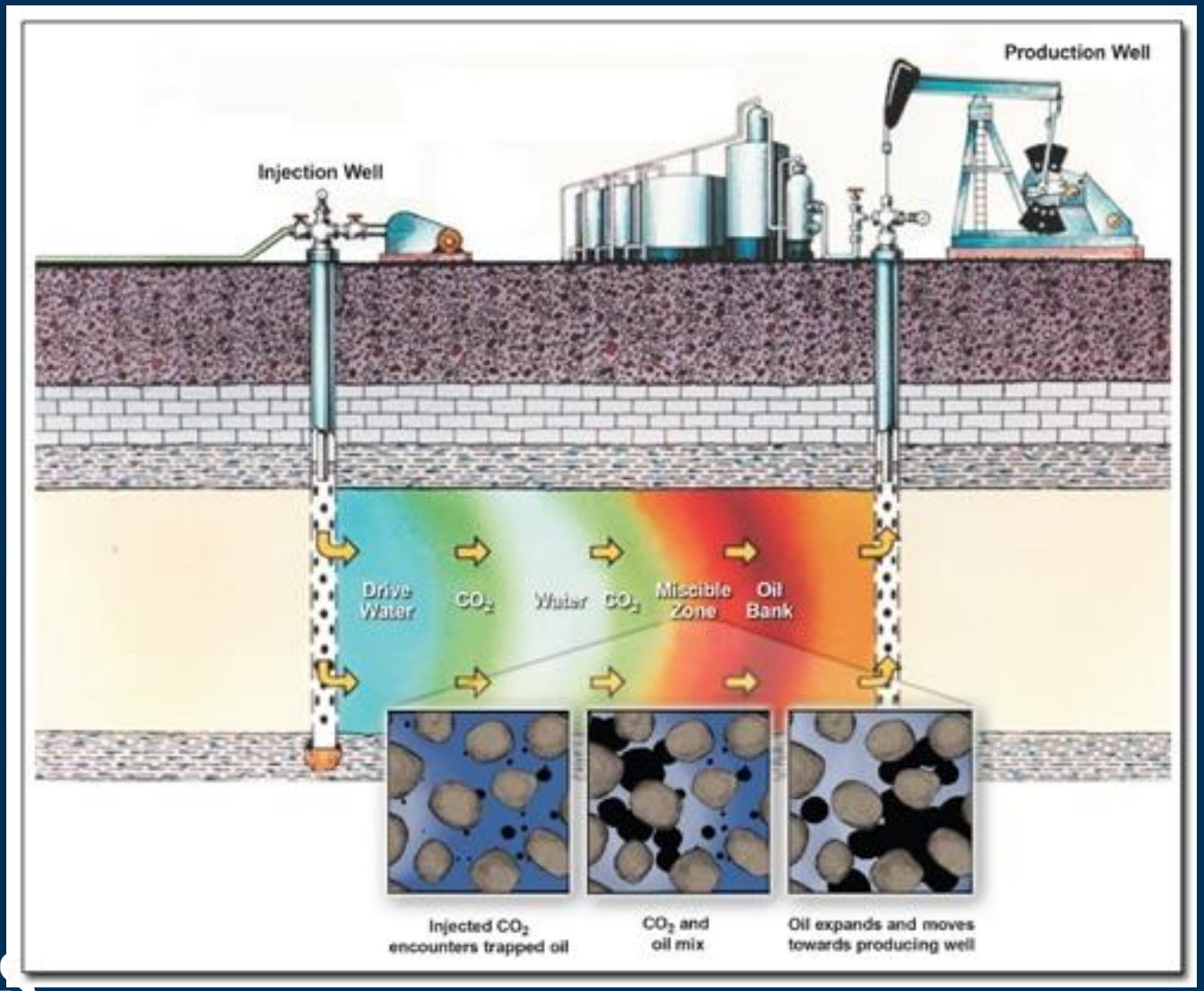
Hydraulically fractured

DOGGR All_Wells_11-19-14

Well Stimulation and Overall Risk to Groundwater Quality

USGS

Well stimulation is taking place in the context of a long history of oil and gas development

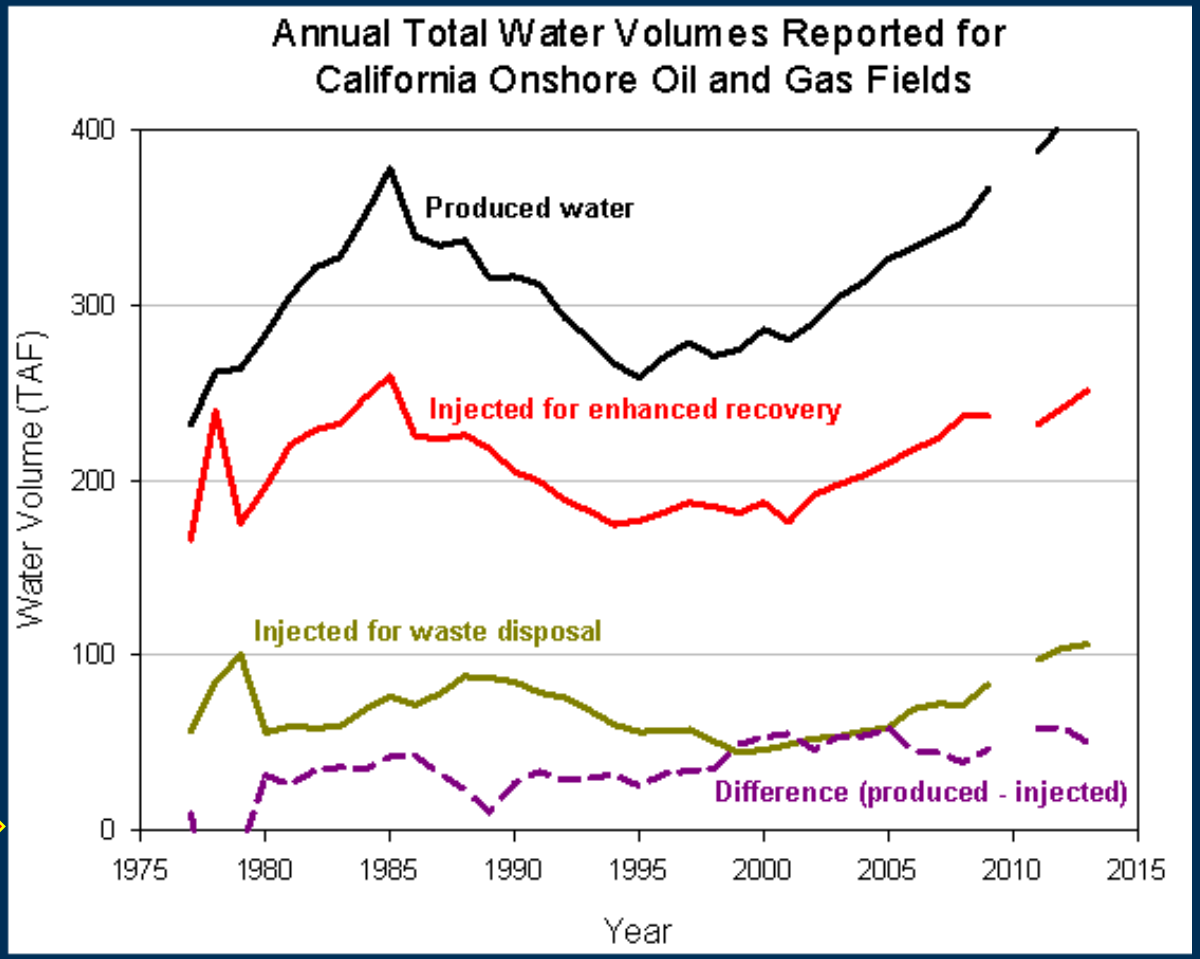


Source: DOE NETL

USGS

Volume of fluid used in well stimulation a very small fraction of fluid flows in oil and gas fields

Well stimulation < 1 TAF/yr

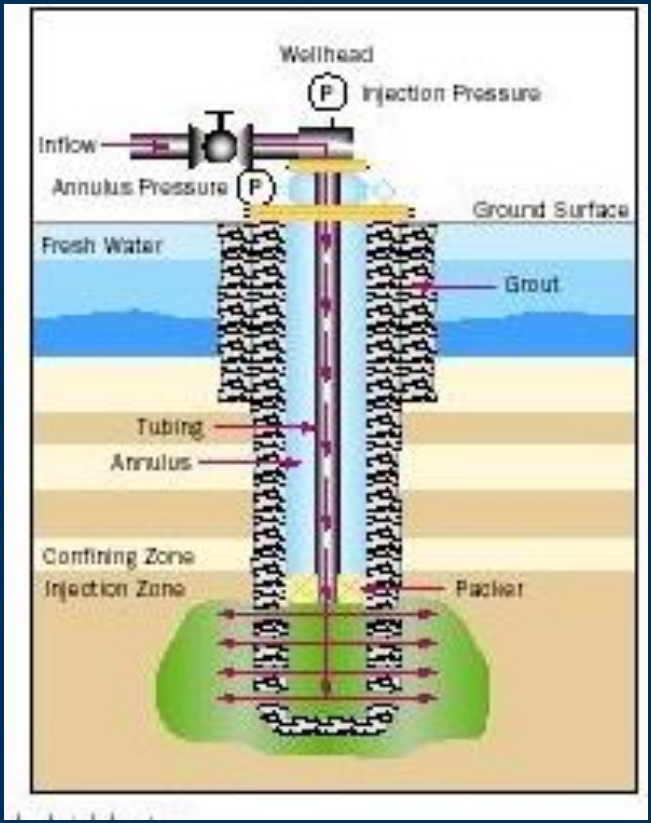


USGS

Well Stimulation Risks to Groundwater Quality Small in Comparison to Other Risks Associated with Oil and Gas Development

USGS

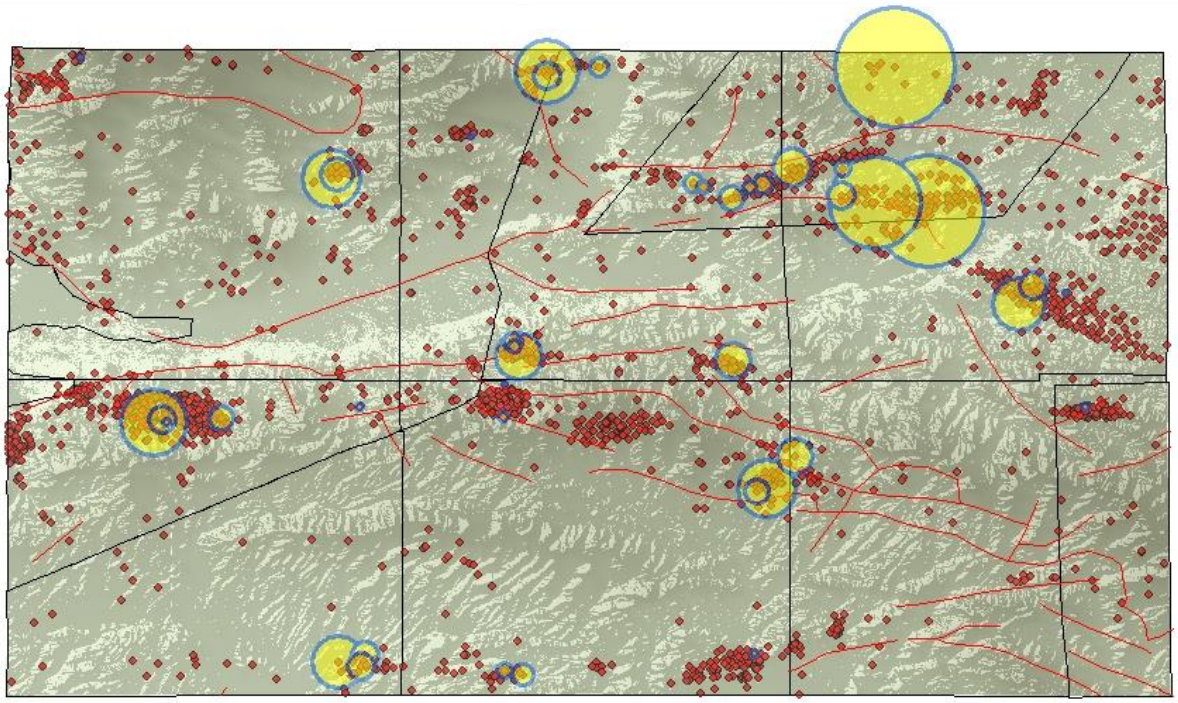
Pathway of Concern #1: Zonal Isolation ??



Zones where fluids—for enhanced recovery, well stimulation, and/or waste produced water—are injected into formations that are not isolated from useable groundwaters

USGS

Waste Disposal Well Injection Volumes



The yellow circles indicate locations and volumes of the study area Waste Injection Wells. These include 47 Active, Idle, and Plugged Wells.

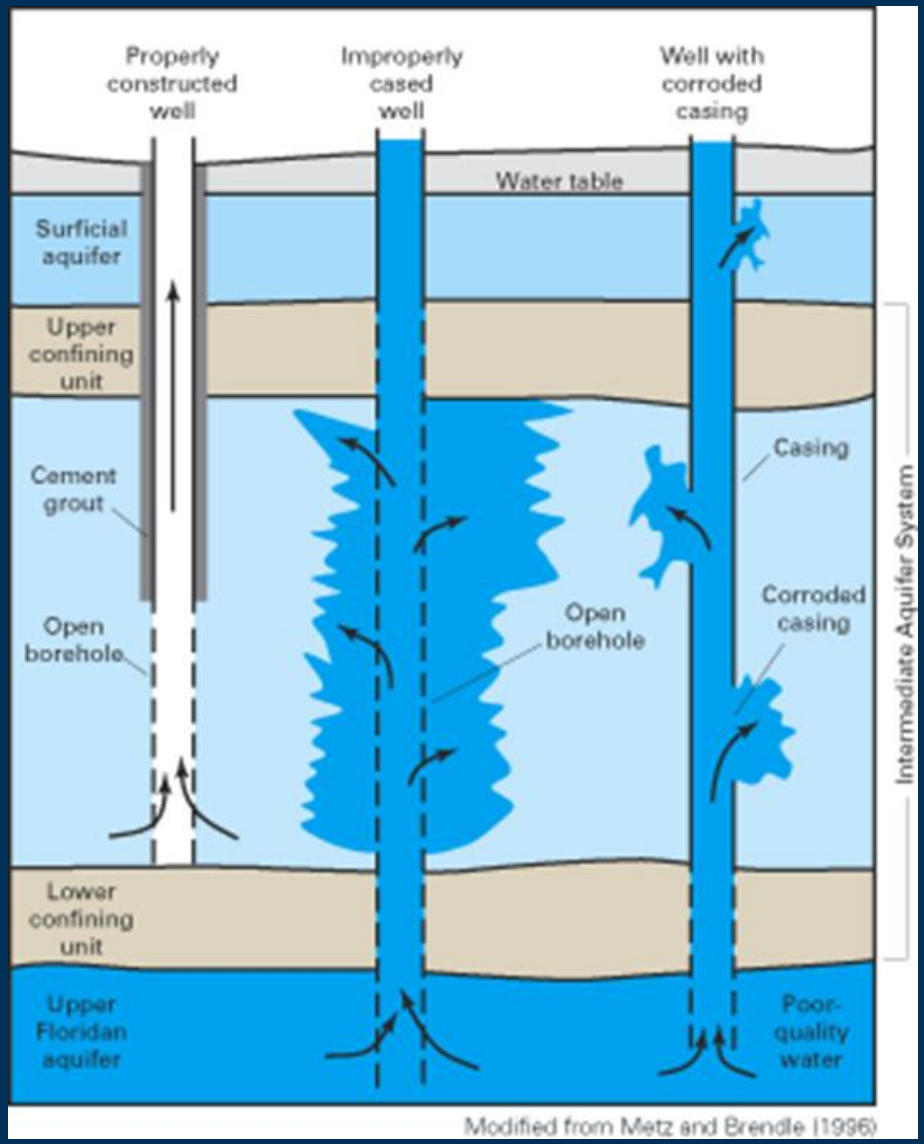
Mapped By: Ed Treguboff 2/25/2015

USGS

Pathway of Concern #2: Surface Activities

USGS

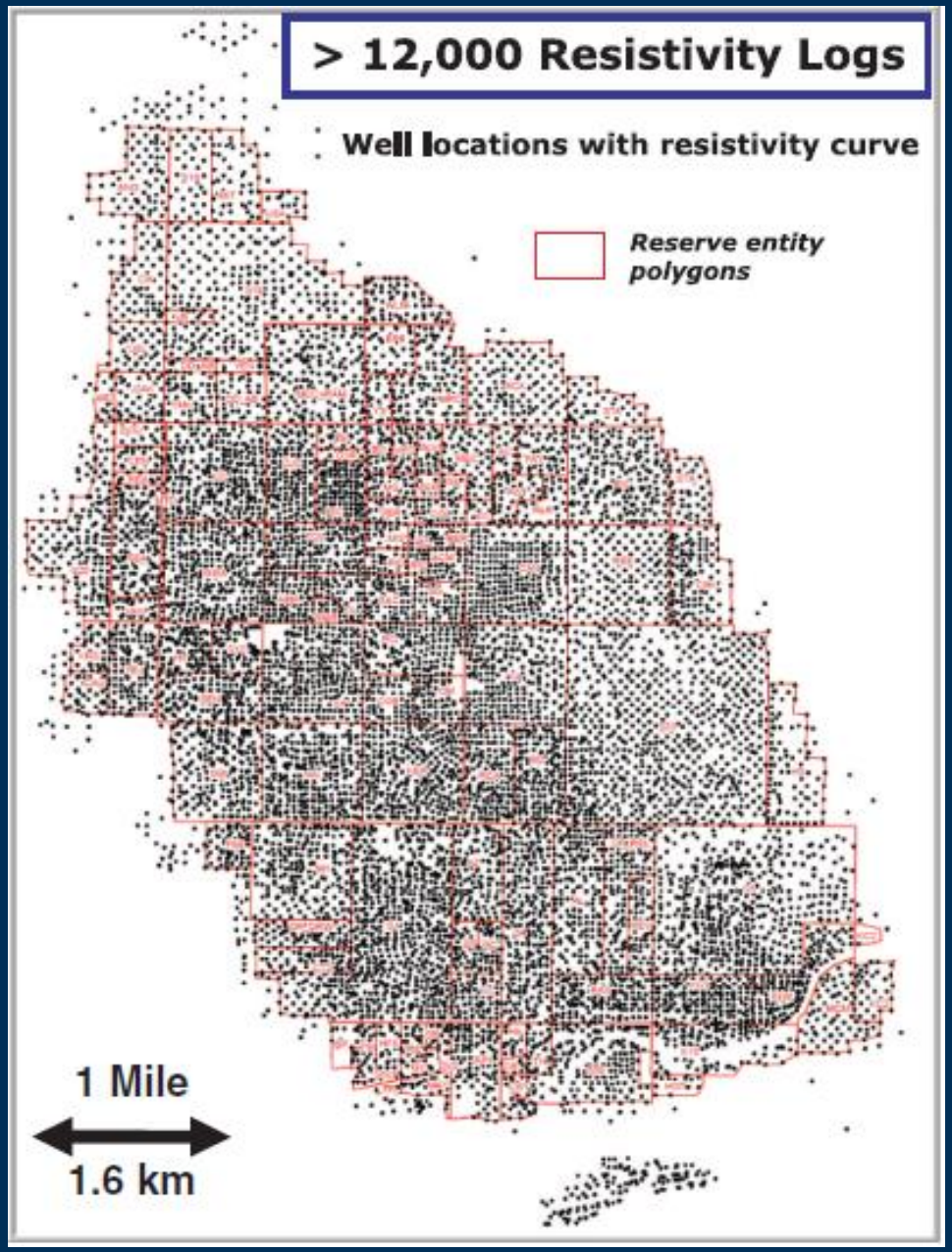
Pathway of Concern #3: Well Integrity



USGS

Wells in Kern River Oil Field with resistivity logs (Beeson and others, 2014)

Of the 168 currently active oil fields greater than 2 mi^2 in size, 31 contain more than 100 known wellbores per square mile



USGS

Suggested Regional Monitoring Program Components

- Zonal Isolation: characterizing the location and extent of risk that any fluid related to oil and gas development is transported outside of isolated zones and towards protected resources and setting up monitoring networks to provide early warning of transport (not distinguishing between WST, EOR or UIC mechanisms)

- Surface Activity Effects: describing how oil and gas activities on the surface have affected shallow groundwater quality in focused areas such as southern Kern County (not duplicating RB site characterization work); and

- Well Integrity: evaluating the potential risk of well integrity failures and inadequate seals to groundwater quality statewide as the infrastructure ages (need the other two done first)

USGS

Exploratory Work

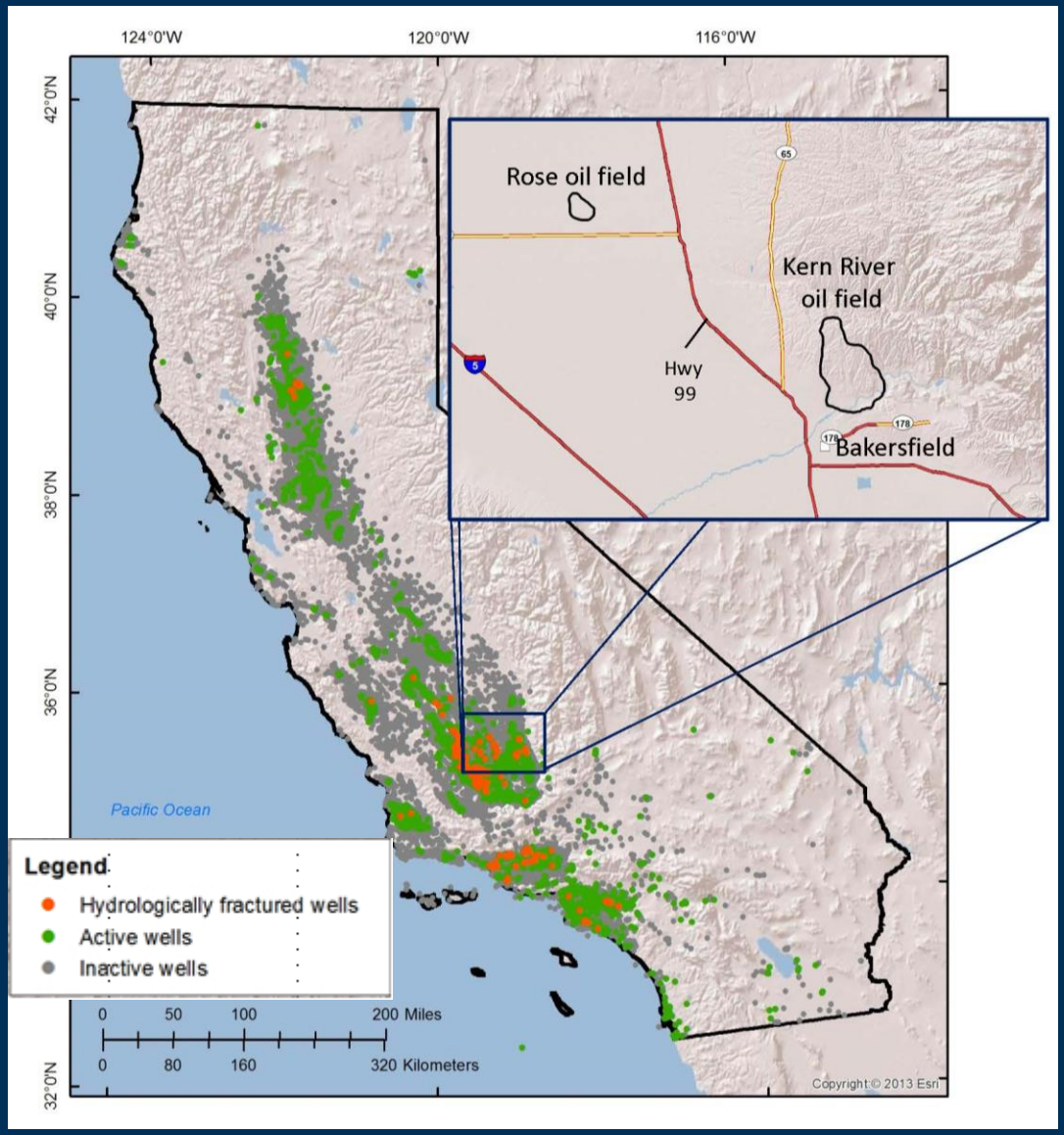
- Reconnaissance-level vulnerability assessment
- Detailed characterization of two oil fields
- Exploratory chemical sampling and analysis

USGS

Proximity of oil and gas zones to groundwater as reconnaissance-level categorization of vulnerability

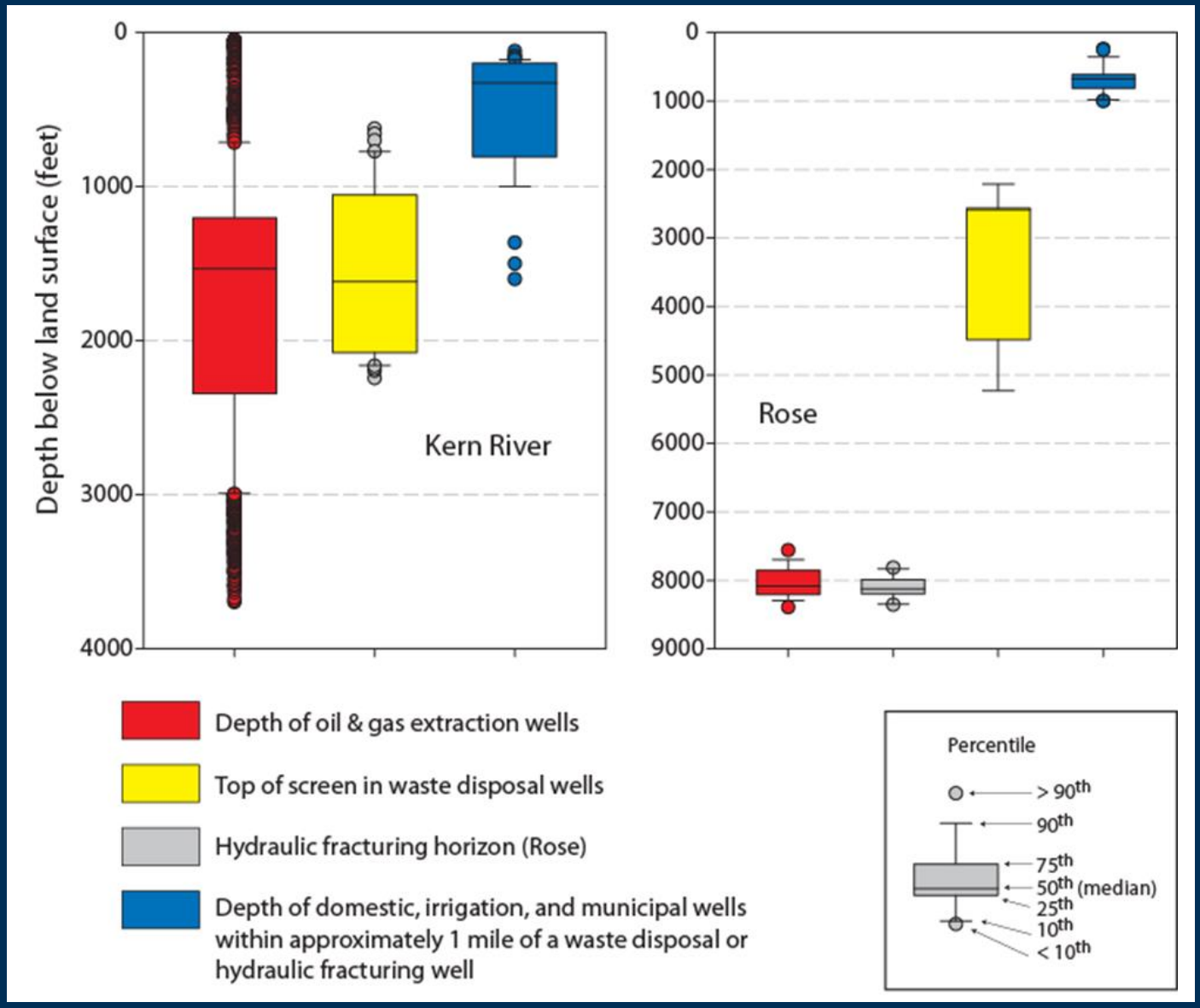
USGS

Proximity Example: Kern River and Rose Oil Fields



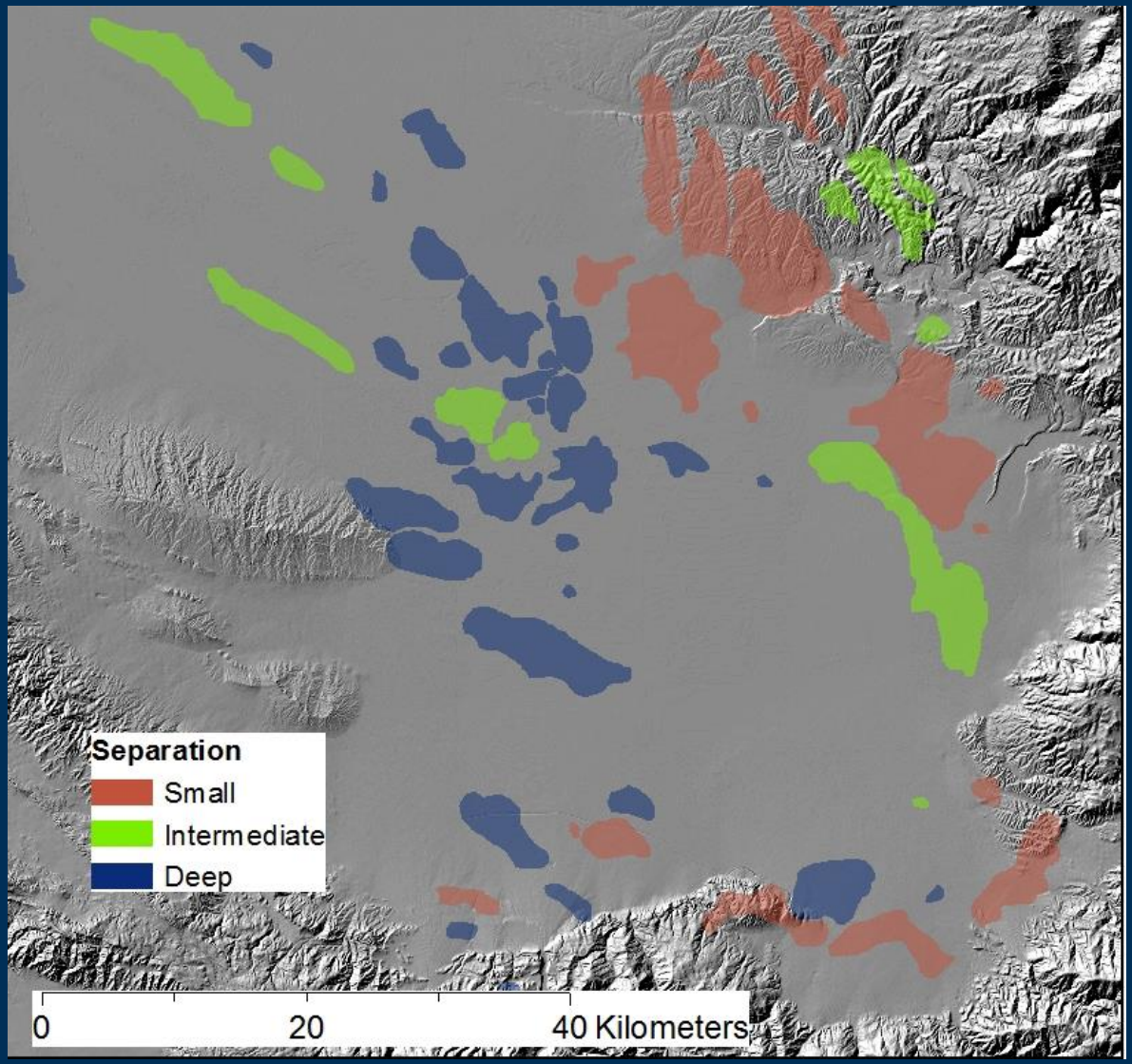
USGS

Proximity Example: Kern River and Rose Oil Fields



USGS

Statewide Proximity Mapping

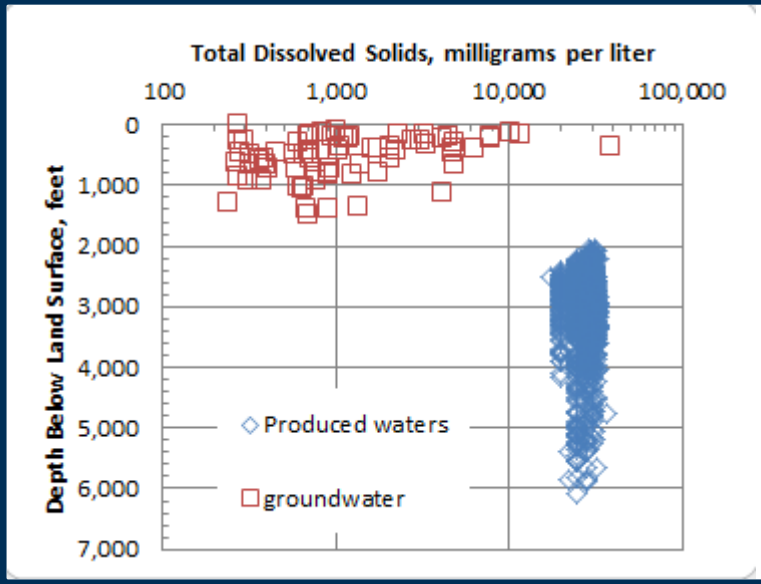


USGS

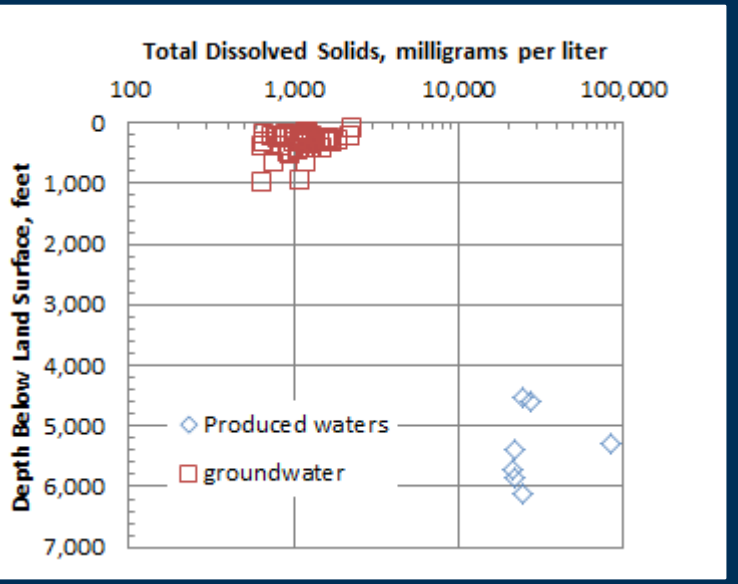
Mapping of Salinity

- Identify 3D extent of groundwater salinity classes, (TDS: > 10,000, 3,000-10,000, < 3,000 mg/L)
- Identify data gaps
- Proposals for filling gaps

Wilmington (LA)



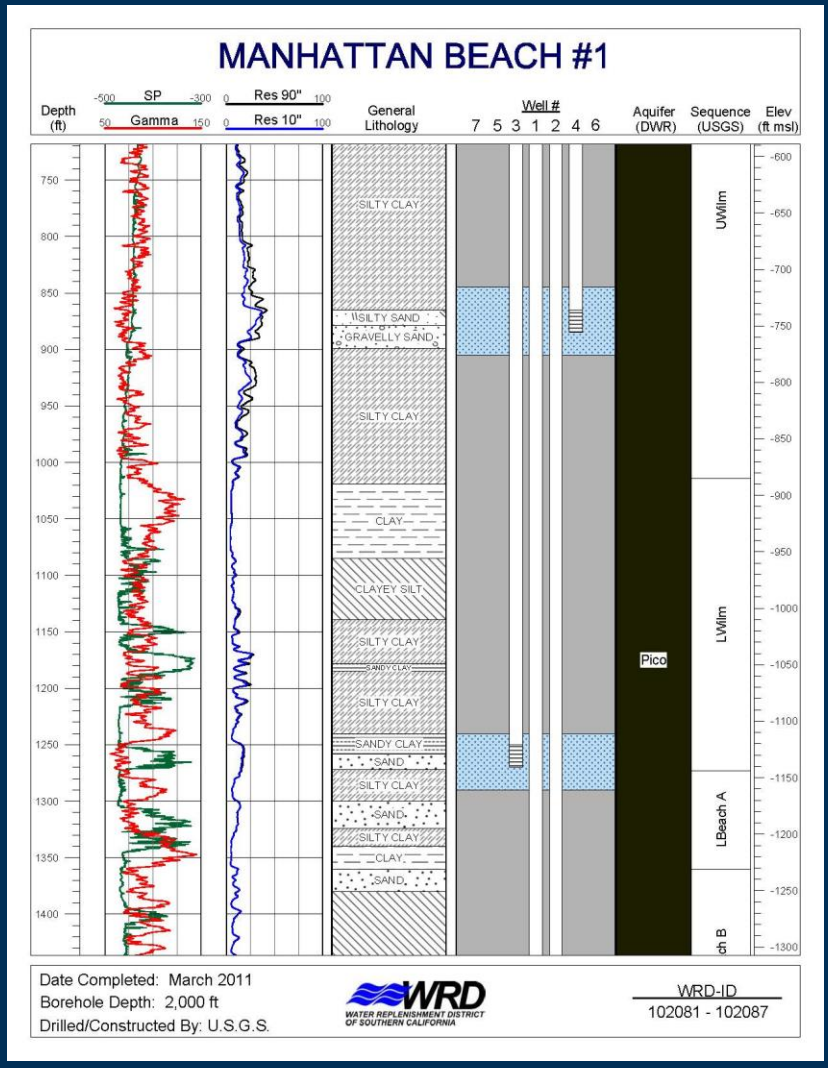
Santa Maria Valley



USGS

Salinity from E-logs to Fill Data Gaps

- Pilot analysis of borehole geophysical log data to estimate gw salinity in selected areas of the LA basin with extensive supporting data (water chemistry, geology, geophysical data) for calibrating estimates



USGS

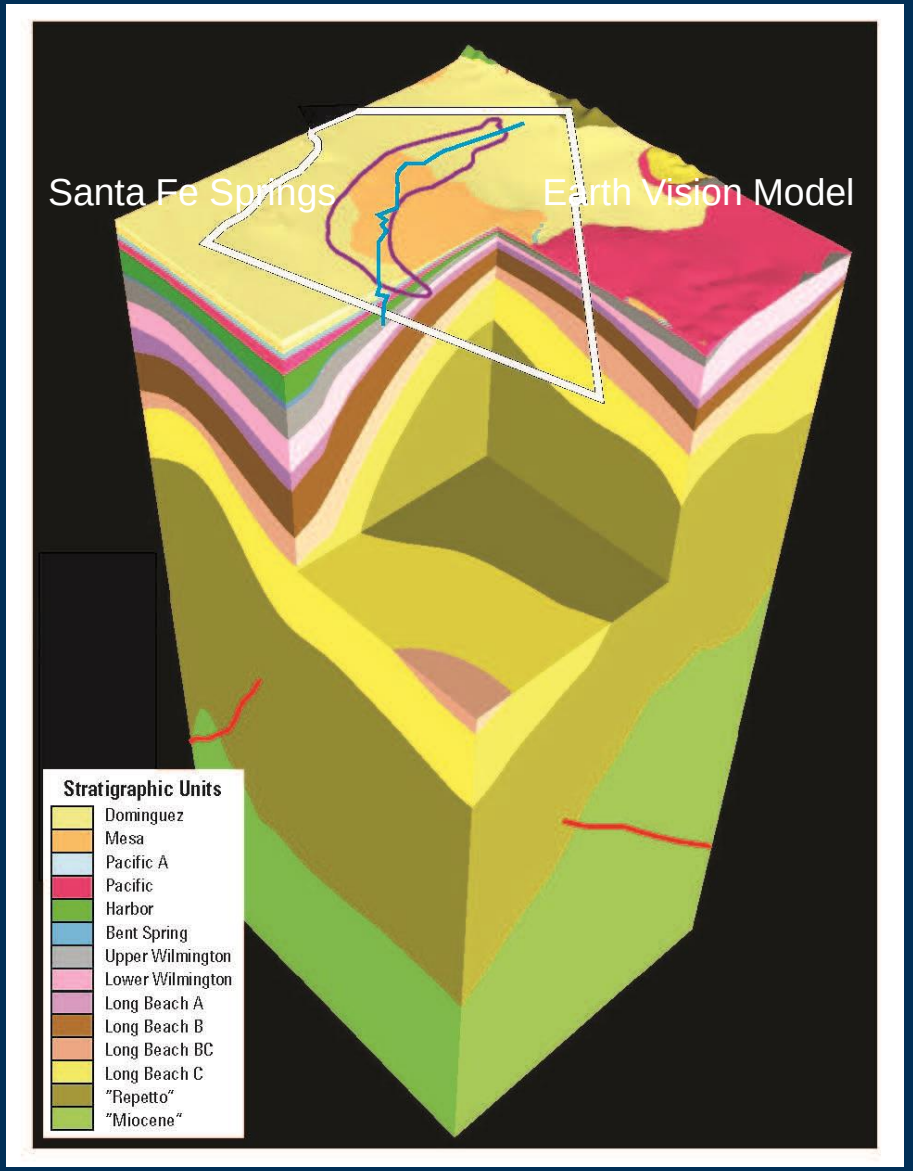
Detailed Field Characterization Pilot

- Purpose was to work through process of using existing data and develop water quality sampling strategies
- Two fields (Santa Fe Springs, Montebello) located in the Los Angeles basin: many oil fields, large gw pumping, and extensive data
- Characterization includes proximity to useable groundwater, number and age of boreholes, geologic structures, well stimulation techniques used, and injection history

USGS

Visualizing the system

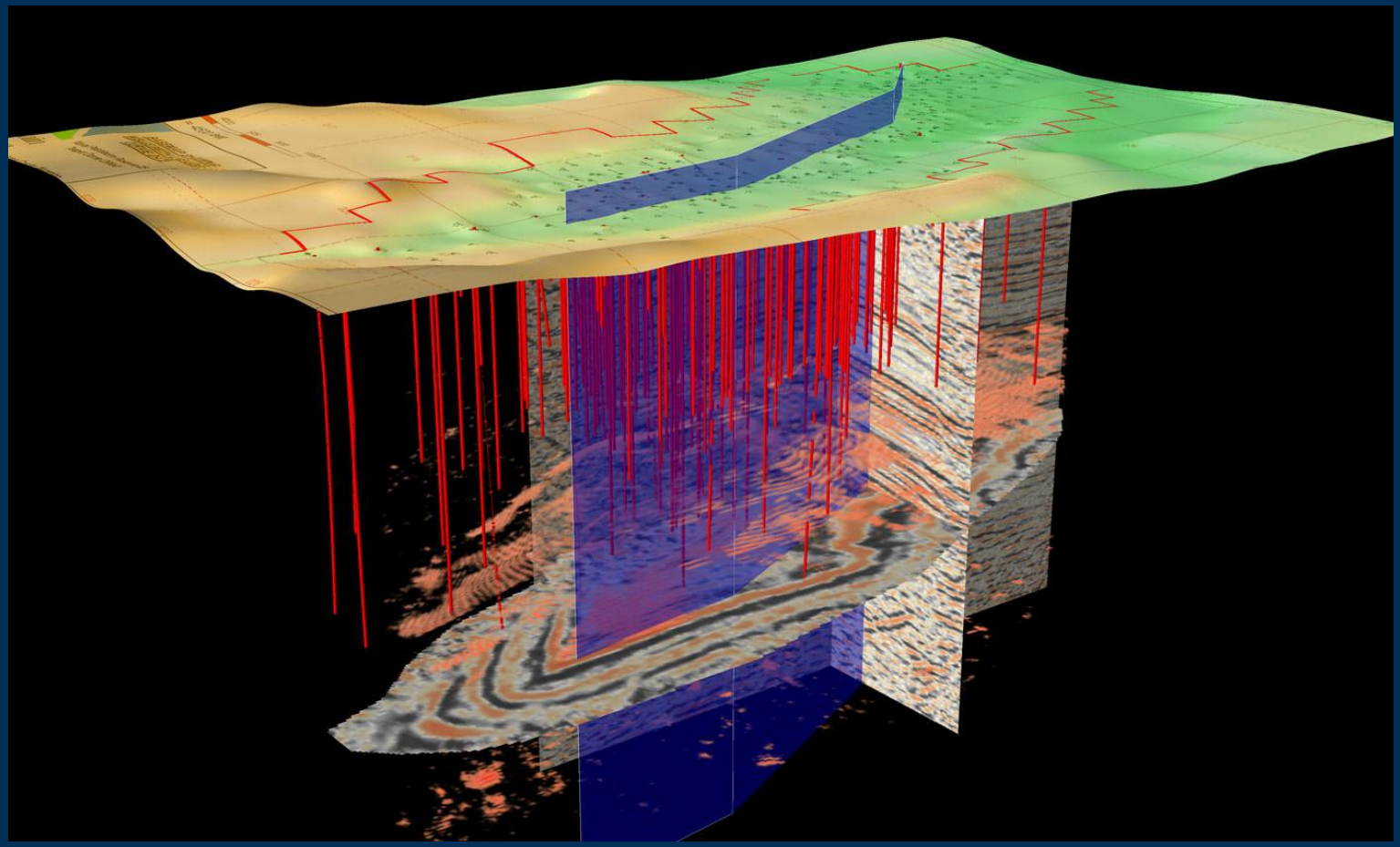
- Existing 3d geologic model
- Will be added:
  - Wells (oil, injection, water)
  - Fresh & saline groundwater distribution from:
    - Water chemistry
    - Geophysical logs
  - Exempted aquifers



Ponti et al. (2014)

Shallowest oil formations

Result--where to monitor



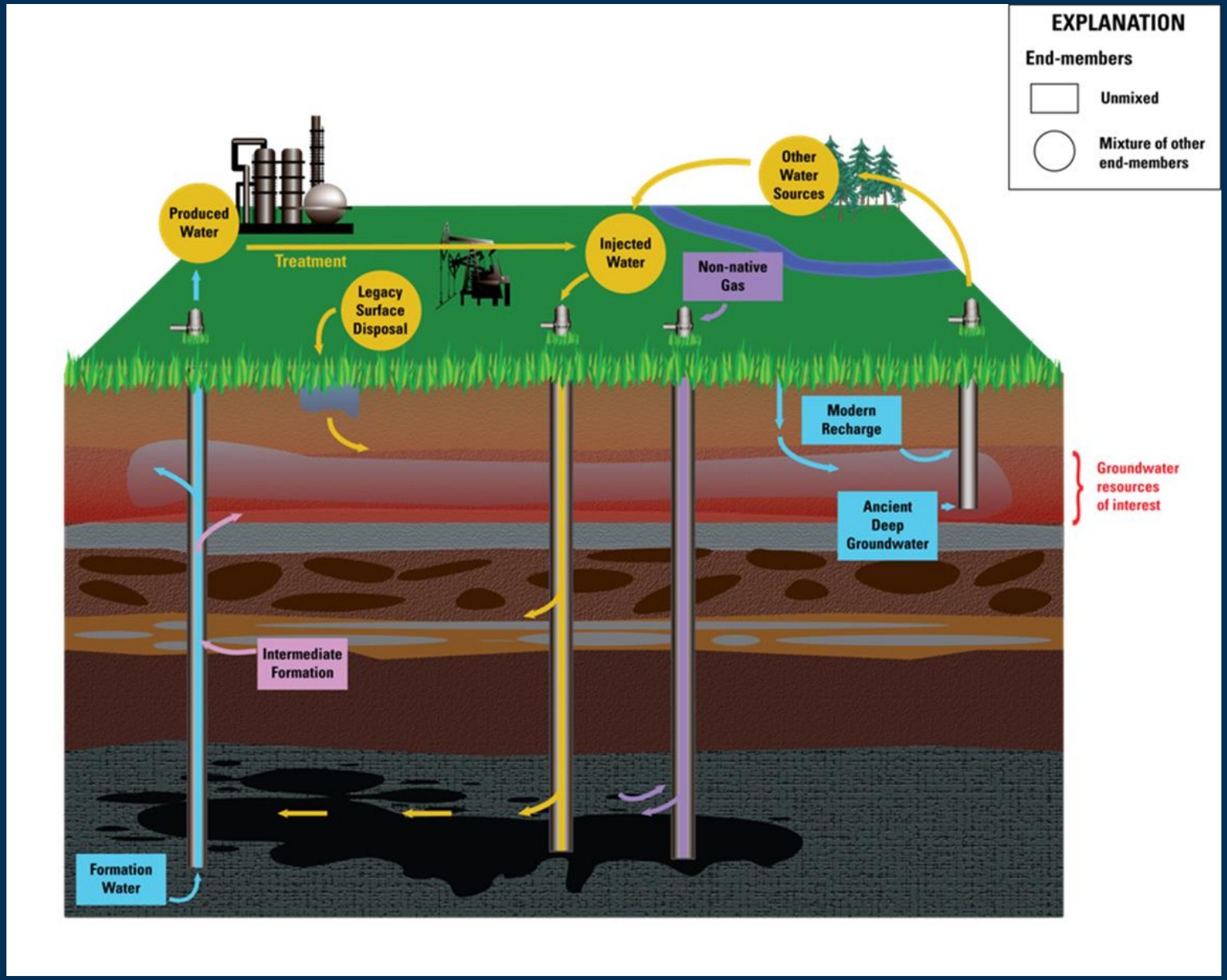
USGS

Analytical Constituents

- Hydrocarbon gas concentrations and isotopes
- Noble and atmospheric gases
- Volatile and semi-volatile organic constituents
- Inorganics (tracers of salts)
- Nutrients
- Naturally occurring radioactive material
- Water and solute isotopes
- Groundwater age dating tracers

USGS

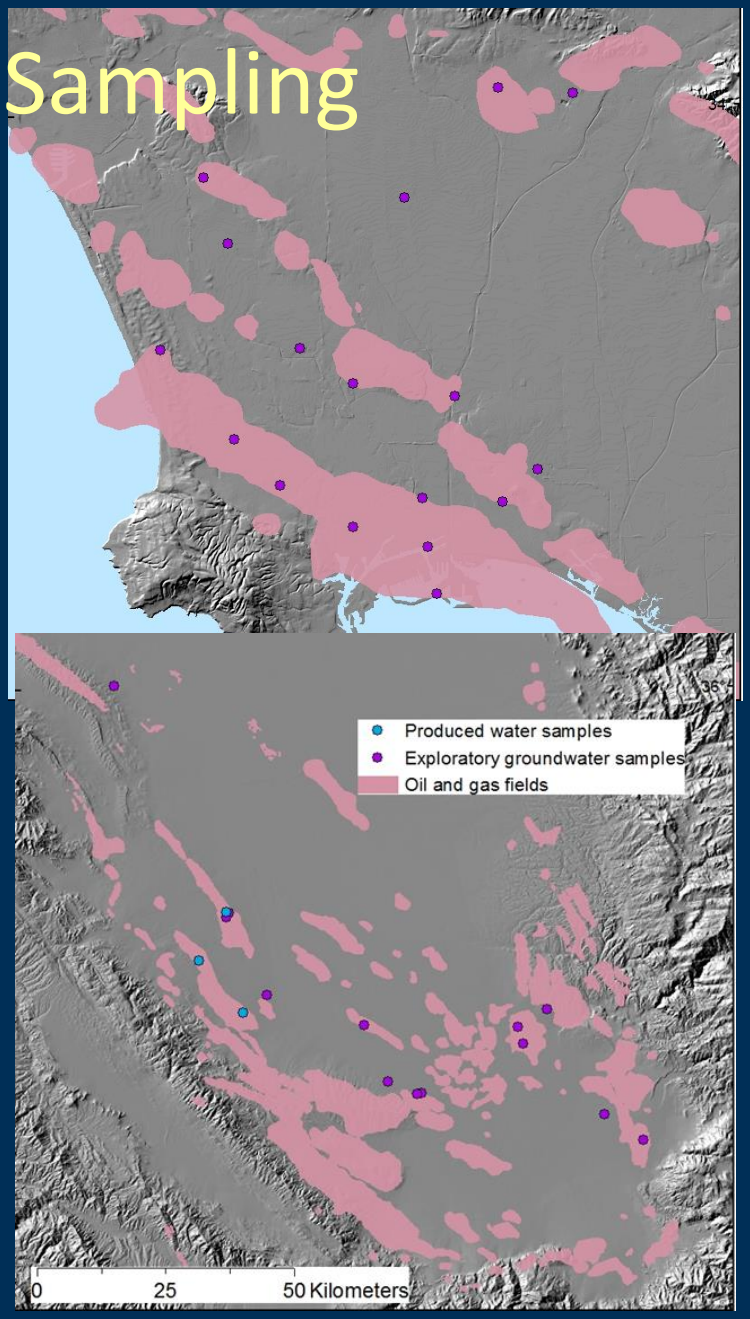
Geochemical end-member mixing model



USGS

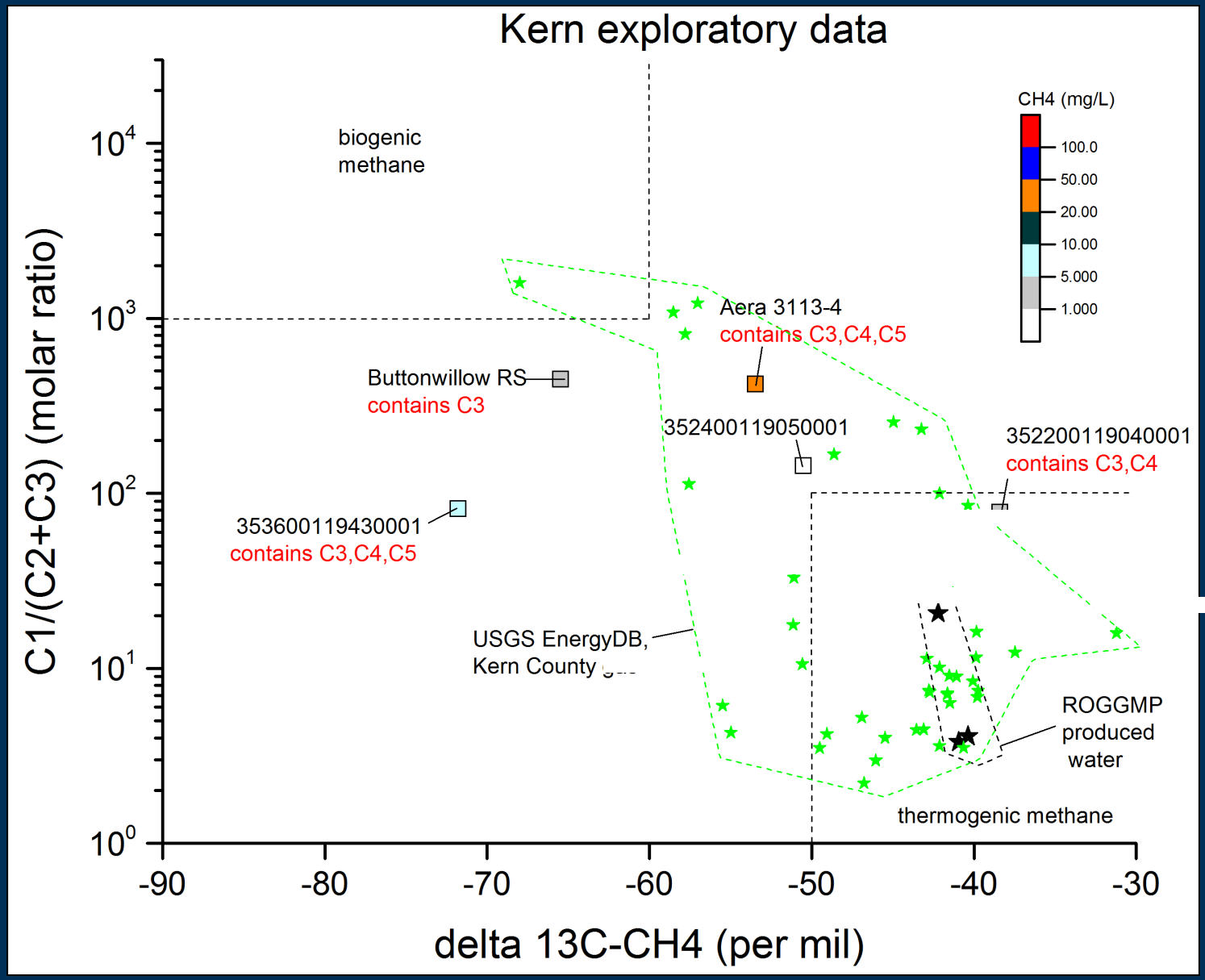
Exploratory Groundwater Sampling

- Determine is we could see geochemical differences in California groundwaters indicative of oil and gas influence
- CAUTION – this was a test of geochemical methods; we don't know if signals were diffusion or other pathways



USGS

Exploratory Sampling Outcome



USGS

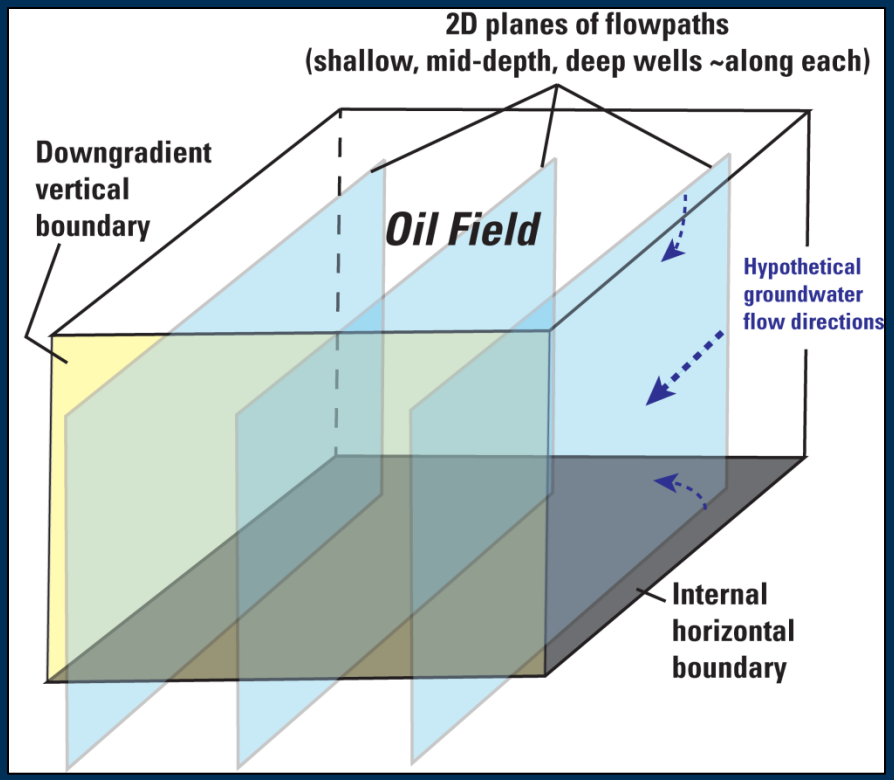
An Approach for Monitoring Groundwater in High Vulnerability Oil Fields

- Monitoring Framework – Zonal Isolation
  - Quasi-vertical boundary at down gradient Administrative boundary of oil field separating O&G activities from down gradient useable gw
  - Quasi-horizontal boundary within oil field separating useable gw from deeper saline/exempted gw
- Monitoring Questions
  - Where are the boundaries located?
  - Are contaminants crossing boundaries? (rates, directions, timing of transport, risk factors)

USGS

Well-Network Design

- Shallow, mid-depth, and deep wells along multiple flow paths in an oil field
- Well types
  - Existing wells preferred
  - Depth-dependent sampling in existing wells
  - Converted O&G wells?
  - Drill new wells



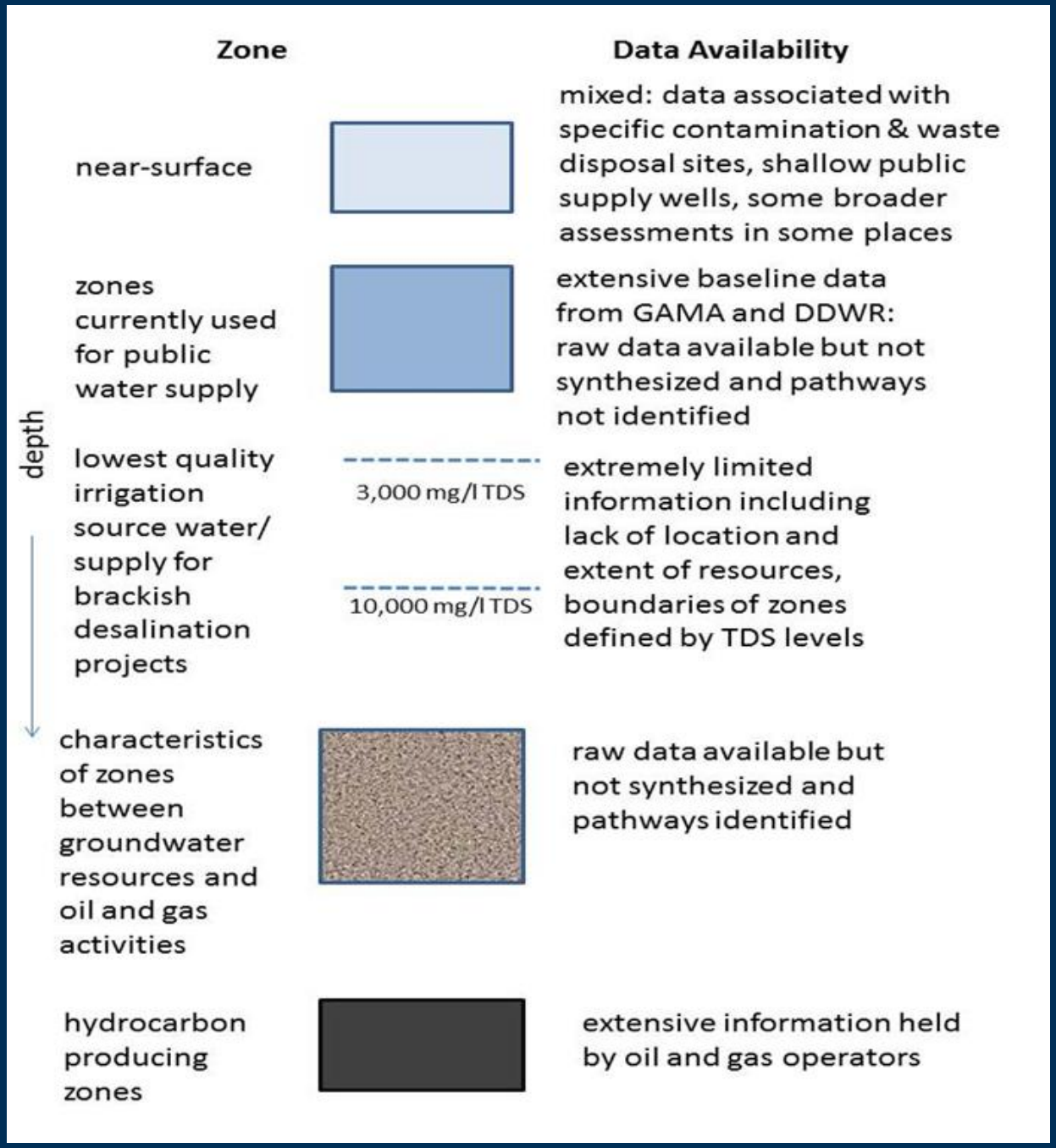
USGS

Summary

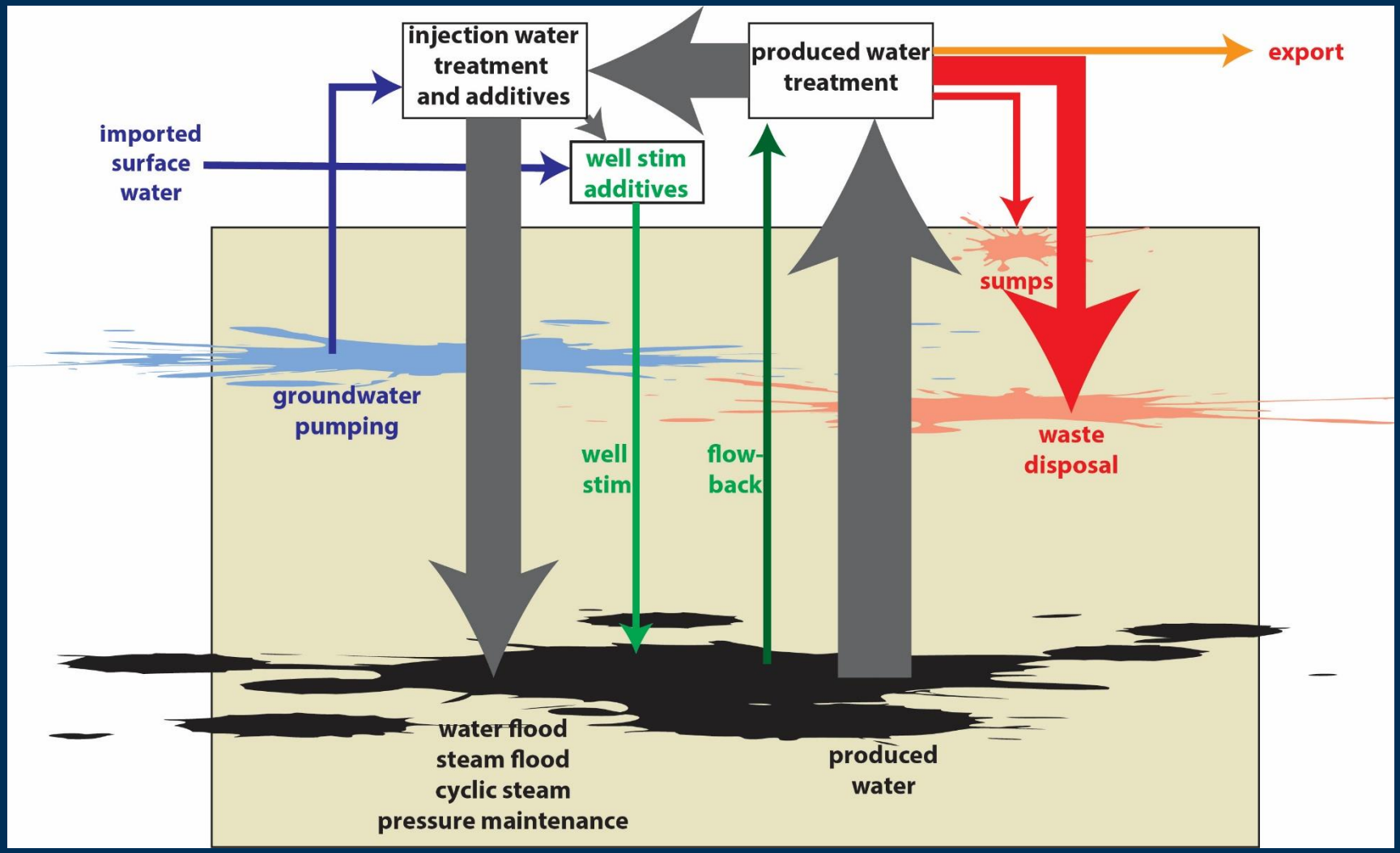
- Three-component regional monitoring program
- Start with zonal isolation component
- Use same analytical suite everywhere; develop library of source characteristics
- Products will support long-term UIC program in addition to SB4 program
- Site-specific approach required
- Availability of wells for sampling and existing but confidential subsurface information major time factors

USGS


USGS


Zone
Data Availability
near-surface
mixed: data associated with specific contamination & waste disposal sites, shallow public supply wells, some broader assessments in some places
zones currently used for public water supply
extensive baseline data from GAMA and DDWR: raw data available but not synthesized and pathways not identified
depth
lowest quality irrigation source water/ supply for brackish desalination projects
3,000 mg/l TDS
10,000 mg/l TDS
extremely limited information including lack of location and extent of resources, boundaries of zones defined by TDS levels
characteristics of zones between groundwater resources and oil and gas activities
raw data available but not synthesized and pathways identified
hydrocarbon producing zones
extensive information held by oil and gas operators

USGS


injection water treatment and additives
produced water treatment
export
imported surface water
well stim additives
sumps
groundwater pumping
well stim
flow-back
waste disposal
water flood
steam flood
cyclic steam
pressure maintenance
produced water

USGS

USGS Discussion Paper

- http://www.waterboards.ca.gov/water_issues/programs/groundwater/sb4/docs/usgs_discussion_paper.pdf

USGS